LABORATORY MANUAL

FOR

SOIL PHYSICS.

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PREFACE.

The laboratory practices described in this manual are designed for one semester's work, during which it is hoped to give the student a knowledge of principles that underlie many common agricultural operations. No very complicated apparatus is required, but great care must be used to have uniform conditions, especially where different soils are to be compared.

In this second edition many changes have been made that the experience of the past three years seemed to indicate as best. Some new Practices have been added, together with cuts, descriptions of apparatus and forms for the data obtained.

In a number of practices students may work together in groups not so large, however, but that each one may have a distinct problem to work out in each practice. This will enable the class to complete the work in one semester which otherwise might not be possible.

ACKNOWLEDGEMENTS.

These laboratory practices were not all originated in the University of Illinois. Nos. 9, 11, 14, 18, 20, 21, and 22 have been adapted to our work from Ohio State University Bulletin No. 6 by Professor William D. Gibbs, formerly of that institution, and Practice 23 was taken from the Manual of Soil Physics of Purdue University. A few of the practices in this manual had been arranged for student use by the late Mr. H. E. Ward, formerly instructor in Soil Physics in the University of Illinois.

I also wish to acknowledge the valuable suggestions received from Professor Clifford Willis, now of South Dakota Agricultural College, and Mr. A. F. Gustafson of this University.

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LIST OF APPARATUS FOR EACH STUDENT.

1	Ring stand	1	Yard cheese cloth
3	Rings (3 sizes)	6	Pint jars
1	Bunsen burner with rubber tubing	1	Pair crucible tongs
1	Desiccator	1	100 cc. graduate
12	Soil pans	1	Wash bottle, 500 cc.
12	Crucibles, 25 cc.	1	Nest of beakers Nos. 1 to 6
6	Crucibles, 50 cc.	2	Funnels, 4 inch
1	Spatula	1	Trinagle, pipestem
1	Camel's hair brush	2	Test tubes
1	Towel	1	Box matches

STOCK SOILS.

The soils commonly used consist of a (1) sand, (2) loam, (3) silt, (4) clay, and (5) peat.

The sand is a white quartz of medium fineness. This is entirely free from organic matter and of course represents an extreme. A sand soil as taken from the field is occasionally used for purpose of comparison.

The loam is a mixture of sand (not over 50 percent) silt, clay and organic matter. This represents a good type.

The silt soil is one in which silt of different grades forms 70 per cent or more of the constituents. It is a very common type of soil, especially in glacial or loessial soil areas. The timber phase of this type is used in the laboratory because it contains less organic matter than the prairie phase.

The clay soil used is a heavy, plastic, sticky, clayey soil, frequently found in bottom lands along large streams. The samples used should contain 30 percent or more of clay.

The peat soil is obtained from peaty swamps or bogs, which are especially common in north central United States. Organic matter usually constitutes about 75 percent of this soil. (Where decomposition has gone on far enough and much clay is mixed with the organic matter, muck soil is found.)

The soils are prepared by being dried and pulverized until they pass through a 2 millimeter sieve.

PRACTICE 1

Determination of Capillary Moisture* in Soils.

Use soils collected according to method given below† and make the determinations in duplicate for surface, subsurface and subsoil.

Weigh carefully six soil pans. Place in each from 100 to 200 grams of the soil and weigh pan and soil quickly to prevent loss of moisture. Let it dry at room temperature for 72 hours, after which weigh at intervals of about 24 hours till a practically constant weight is obtained. The loss of weight is the capillary moisture. Express your results in grams, and after the completion of the next exercise express the results in percent of the water-free soil. Use these air-dry soils for Practice 2.

Express in tabular form the capillary moisture in grams and percent of water-free soil.

*The moisture content will always be expressed as percent of the water-free soil in these exercises unless otherwise stated.

†For this practice and also for Practice 5 the students are required to collect their own samples. For this purpose a one and one-half inch or a two-inch auger with an extension making it 40 inches long is used. In collecting samples for moisture determinations, expose the soil as little as possible to the air before putting in jars. Collect the surface soil to the depth of the plow line, usually about 7 inches. After this part of the sample is removed, the hole is enlarged sufficiently so that the subsurface soil may be taken without coming in contact with the surface soil. Take the subsurface sample to the subsoil line as indicated by the change in color, texture and physical composition. Commonly this line is found at a depth of 16 to20 inches. Enlarge and clean out the hole as before. Since the change from subsurface to subsoil is not a sharp line but usually somewhat gradual, we discard about two inches of the intermediate mixture. The subsoil is then collected to a depth of 40 inches, if possible.

In some soils the subsurface layer may be absent, the subsoil being reached by the plow, while in others, as in peaty and sandy soils, no true subsoil may be found within 40 inches of the surface. In such cases only two samples are taken.

PRACTICE 1

Stratum	Surface		Subsurface		Subsoil	
Sample	1	2	1	2	1	2
Weight of pan............	......	......	......	......	......	......
Weight of pan + moist soil.....	......	......	......	......	.....	......
Weight of pan + air-dry soil...	......	......	......	......	......	......
Loss in grams...............	.....	......	......	......	......	......
Weight of water-free soil.......	......	......	....	...	. ....	.....
Capillary moisture in % of water-free soil..........	......	......	......	....	......	......

PRACTICE 2

Determination of Hygroscopic Moisture.

Use air-dried soils from Practice 1. Mark and weigh the necessary number of crucibles to run duplicates of each stratum. Place about 10 grams of air-dried soil in each crucible and weigh. It is best to weigh all of the duplicate samples out at the same time so as to get them under the same conditions as to moisture. The hygroscopic moisture of a soil varies with the relative humidity and temperature of the atmosphere. Heat in an oven at about 100° C. for at least five hours. Cool in a desiccator and weigh rapidly to prevent absorption of moisture from the air. The loss of weight is the hygroscopic moisture.

Express in tabular form the loss in grams and in percent of the water-free soil. Also the total moisture of the samples in percent of water-free soil.

PRACTICE 2

Stratum	Surface		Subsurface		Subsoil	
Sample	1	2	1	2	1	2
Weight of crucible............	...	......	.....	......	......	......
Weight of crucible+air-dry soil	......	......	....	......	......	......
Weight of crucible + water-free soil............	.....	....	......	.....	......	......
Loss in grams..............	..	......	......	.....	.....	......
Hygroscopic moisture in % of water-free soil...... ...	......	......	......	......	.....	....
Av. per cent. of hygroscopic water..................	....		....		....	
Av. per cent. of capillary water	....		....		....	
Total water................	....		....		....	

PRACTICE 3

Effects of Drainage on Temperature of a Soil.*

Two wooden trays 3 by 4 feet and six inches deep, one lined with zinc to prevent the loss of water and the other made so as to allow drainage, are filled with the same kind of soil. Water is added to each till drainage begins in the latter. After three or four days the temperature of each at 1, 2, and 4 inches in depth is determined hourly on a clear day.

Explain differences in temperature.

Why is clay land liable to be cold?

*This and the following Practice logically come later in the course, but the season here makes it necessary to give it early in either semester. Better results may be obtained by conducting these experiments before the weather gets too cold in the fall or too hot in the spring.

PRACTICE 3

Time	Ther. 1 inch deep		Ther. 2 inches deep		Ther. 4 inches deep	
	Drain'd	Un-drained	Drain'd	Un-drained	Drain'd	Un-drained
8 o'clock	....	....	....	....	....	....
9 "	....	... ...	....	....	....	....
10 "	... .	....	....	....	.. ..	....
11 "	....	.. . ...	....	....	....	....
12 "	....	....	....	....	....	....
1 "	....	....	....	....	....	....
2 "	....	....	....	....	....	....
3 "	....	....	....	... .	....	....
4 "	....	....	....	.. ..	... .	....
5 "	....	....	....	....	....	....

PRACTICE 4

EFFECTS OF COLOR OF SOIL ON TEMPERATURE.

Fill large wooden tray 6 feet long, 3 feet wide and 6 inches deep with very light colored soil, gray silt loam, well pulverized. Divide the tray lengthwise into halves and divide each half into six plots and plant the same kind of seed in the opposite plots putting the same number in each but covering those in one half of the tray ¾ inch and the other, ½ inch deep. Then cover the latter with ¼ inch of black soil so that all of the light colored soil is covered. Observe the number of plants up each morning and evening, keeping a careful record of the number coming up each day.

Select a clear day and make observations on the temperature of each half of the tray. Insert thermometers 1, 2, and 4 inches in depth, also place one, one inch above surface of each kind of soil, and take hourly readings from 8 a. m. to 5 p. m. Keep all parts of tray equally moist.

Each student may look after the planting of a single plot but he must make observations on all plots in the tray and keep results in tabular form.

Which tray shows the higher temperature? Why?

Why can you see the corn rows on the low black land sooner after planting than upon the higher lighter colored soil?

PRACTICE 4

	Location of Ther.	Time									
		8	9	10	11	12	1	2	3	4	5
Dark Soil	1 inch above										
	1 inch below										
	2 inches below										
	4 inches below										
Light Soil	1 inch above										
	1 inch below										
	2 inches below										
	4 inches below										

Number of plants up after number days indicated below:

Number of days	Light Soil						Dark Soil					
	Corn	Wheat	Beans	Cow peas			Corn	Wheat	Beans	Cow peas		

PRACTICE 5

Determination of Total Moisture in the Same Soil Under Different Conditions.

Collect samples of surface, subsurface and subsoil* from the following places: (1) Sod, (2) Tilled field, (3) Forest. In collecting these samples care should be taken to secure them from as small an area as possible so that soil conditions may be uniform. Expose the samples as little as possible to the air while taking them. After taking them to the laboratory, the contents of the jars should be thoroughly mixed by shaking. The condition of the weather at the time the samples are taken and also the amount of rainfall within the week previous should be noted.

Make the determinations in duplicate. Weigh 6 soil pans and use 100 grams or more of each soil. Weigh rapidly to prevent loss by evaporation. Place in an oven and leave at least five hours. Cool to the room temperature and weigh at once. The loss of weight represents the total water content.

It would be well for three students to work together, one taking the surface, another the subsurface, and the third the subsoil. These results may be compared.

Explain differences in moisture content of the soils.

PRACTICE 5

Sod

Student	Stratum	Wt. of moist soil	Wt. of water-free-soil	Loss in Grams	Percent moisture
....	Surface	....	....	....	....
....	Subsurface ..	....	....	....	....
....	1st Subsoil...	....	....	....	....
....	2nd Subsoil..	....	....	....	....

*In collecting the subsoil for moisture determination it is sometimes well to divide it into two equal parts as to depth.

TILLED FIELD

	Surface				
	Subsurface				
	1st Subsoil				
	2nd Subsoil				

FOREST

	Surface				
	Subsurface				
	1st Subsoil				
	2nd Subsoil				

PRACTICE 6

Determination of the Variation in the Hygroscopic Capacity of Soils.

In this exercise each student will use air-dried soils provided for the purpose. These are sand, loam, silt, clay and peat.

Determine the percent of moisture lost when heated for 5 hours at 100° C. This is the hygroscopic moisture. Express in percent of water-free soil. Care must be taken to weigh out all samples at the same time to avoid any change in the amount of moisture due to a change in relative humidity.

Explain differences between clay and sand.

Between peat and sand.

PRACTICE 6

Soil	Sand		Loam		Silt		Clay		Peat	
Sample	1	2	1	2	1	2	1	2	1	2
Weight of air-dry soil....	....	...	....	...	....	....	...	....	...	....
Weight of water-free soil.	...	....	....	....	...	...	....	...	....	....
Loss in grams........	. ..	...	....	....	....	....	......	....	....	....
Percent of hygroscopic moisture............	....	....	....	....	....	....	....	....	....	....
Average percent.... .	....		... ...		....		.. ....		....	

PRACTICE 7

Determination of Flocculating Action of Lime.

Take four bottles and in one put 200 cc. of distilled water, as a check, in another 200 cc. of .1 percent solution of lime, in another 200 cc. .01 percent and in the fourth .001 percent solution. Add to each, three grams of finely ground clay and shake for ten or fifteen minutes. After shaking take out a drop from the check and .1 percent solution and examine under a microscope with a high power. Then pour some of the contents of the bottles into tubes and whirl in the centrifuge, stopping every two or three minutes to note the effect upon the clearness. Whirl for at least fifteen minutes. After centrifugation, pour the contents of the tubes into their respective bottles, shake thoroughly and set aside, observing them occasionally to determine the time required for complete sedimentation in each case.

Make sketches of the appearance of the check and the 0.1 percent solution under the microscope.

Which is thrown down first by the centrifuge? Why?

What practical application of this principle in farm practice?

PRACTICE 7

	Time to Centrifugate	Time for Sedimentation
0.1 % solution	....	....
0.01 % solution...	....	....
0.001 % solution..	....	....
Check.	....	....

PRACTICE 8

Determination of the Effects of Lime on Plastic Soils.

Two students may work together in this experiment.

Weigh out 6,300-gram samples of the clay soil using them as follows: To sample

No. 1, check, add no lime.
No. 2 add .5 gr. of air slacked lime.
No. 3 add 1. gr. of air slacked lime.
No. 4 add 5. gr. of air slacked lime.
No. 5 add 10 gr. of air slacked lime.
No. 6 add 10 gr. sand.

Mix each sample thoroughly in a soil pan with the lime and add just enough water to make plastic.

Fill the semicircular moulds, first placing a damp thin cloth in it to facilitate the removal of the clay. Make duplicates of each number, being careful to compress each to the same degree. Place on a cloth in a soil pan and dry in an oven for 5 hours at 100° C.

Test the strength of each brick by supporting the ends so as to allow just 3 inches between points of support. Hang weight pan in middle of brick and determine the weight necessary to break each.

Explain the effect of lime.

Why does the sand not have as much effect as the lime on the breaking strength?

PRACTICE 8.

	1st Trial	2nd Trial	Average
Check.—No. lime	....	....	....
0.5 grams of lime	....	....	....
1. gram of lime	....	....	....
5. grams of lime	....	....	....
10. grams of lime	....	....	....
10. grams of sand....	....	....	....

PRACTICE 9

Determination of the Volume Weight and Apparent Specific Gravity of Soils.

The volume weight of a soil is the weight of a certain unit of volume and the cubic centimeter is taken as this unit. In determining the apparent specific gravity, the pore space is not taken into account. This gives a result much less, numerically, than the real specific gravity.

Find the volume weight and apparent specific gravity of sand, loam, silt, clay and peat.

Weigh an empty and thoroughly cleaned soil tube.* Fill the tube with one of the soils to be tested by simply pouring the soil in loosely till it reaches the crease near the top, being careful not to compact the soil by jarring or jolting. Weigh, empty and then fill again with the same soil in the same way, using the average of the two weights of soil from which to determine the volume weight and apparent specific gravity. Treat each soil in the same way. Determine the amount of water-free soil in each case by using the percent of hygroscopic moisture found in Practice 6. Find volume of soil tube by filling with water to the crease and weighing. The weight in grams will give the volume in cubic centimeters since one cc. of water weighs approximately one gram. The weight of the soil divided by the volume of the tube will give the weight of one cubic centimeter of soil or the volume weight of soil. Numerically, this is the apparent specific gravity.

$$\text{Then}\ \frac{\text{Volume weight of soil}}{\text{Volume weight of water}} = \text{Apparent Specific Gravity of Soil.}$$

Repeat the above process with each soil but use the compacting machine in filling the tubes, allowing the weight to fall three times from the 12-inch mark upon each measure of soil.

The volume weight and apparent specific gravity of soils varies with the amount of compaction. A freshly plowed field is much lighter per cubic foot than one compacted by rains, tramping or by means of the roller.

Why is the apparent specific gravity of sand higher than that of loam?

Why is the apparent specific gravity of peat so low?

Sand has less pore space than clay.

How will this affect the apparent specific gravity?

What would be the weight of a cubic foot of each kind of soil both compact and loose?

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* A galvanized iron tube two inches inside diameter and 12 inches long, closed at one end. A crease one inch from the top indicates the height to which it may be filled.

PRACTICE 9

Soils	Sand		Loam		Silt		Clay		Peat	
Compaction	L*	C	L	C	L	C	L	C	L	C
Weight of tube..........	...	....	....	...	....	...	....	...	....	....
Weight of tube + air-dry soil...... 1st trial.	....	...	....	...	....	....	....	....	....	....
Weight of tube + air-dry soil...... 2nd trial	....	....	...	...	....	....	....	...	....	....
Av. of trials.........	...	....	...	....	....	...	....	....	.	....
Percent of hygroscopic moisture.......	....	....	....	....	...	....	....	....	....	....
Weight of water-free soil.	....	....	....	....	....	....	....	....	....	....
No. of cc. of water to fill tube...............	....	....	....	....	...	....	....	...	....	....
Apparent specific gravity.	....	..	....	....	....	....	....	....	....	....
Weight of 1 cubic foot...	....	....	....	....	....	....	....	....	....	....

*L = loose, C = compact.

PRACTICE 10

Determination of the Apparent Specific Gravity of Surface Soil Under Field Conditions.

Take a tube* provided for the purpose and force it into the ground to the depth of six inches. Remove soil to a weighed pan and dry in the oven at 100° C. for at least ten hours. Find volume of the soil taken and divide the weight of the water-free soil by this. The result will be the apparent specific gravity.

The apparent specific gravity of soils in the field may be taken as an approximate indication of the tilth, since the better the tilth the less the apparent specific gravity for the same kind of soil. This is due to the fact that soils in good tilth are looser on account of the presence of a larger percent of organic matter and better granulation. The apparent specific gravity of a continuously cropped soil is higher than one having proper rotations. Why?

What would be the weight of a cubic foot of soil under the above conditions?

*An iron or brass tube three inches in diameter with a cutting edge. Very heavy galvanized iron will do.

PRACTICE 10

	Sample 1	Sample 2
Weight of pan		
Weight of pan + soil		
Weight of soil		
Weight of water		
Weight of water-free soil		
Volume of tube in cc		
Apparent specific gravity		
Weight of a cu. ft. of soil		

PRACTICE 11

Determination of Real Specific Gravity of Soils. Picnometer Method.

Use sand, loam, silt, clay and peat.

Fill a picnometer to the end of the capillary tube with distilled water whose temperature is known. Wipe dry and weigh. Pour out about half of the water and add about ten grams of soil (about half as much peat) that has been carefully weighed. It is a good plan to weigh the flask just before the soil is added and again just after, the difference being the weight of the soil. In this case the soil need not be previously weighed.

Boil gently for a few minutes in the water bath, sand bath or on an asbestos mat to drive out the air from the soil. Refill with distilled water, bring to the same temperature as before and weigh. Determine the amount of water-free soil, using the percent of hygroscopic moisture found in Practice 6. The weight of the flask of water plus the weight of the soil, minus the weight of the flask containing the soil gives the weight of water displaced by the soil. Calculate the specific gravity and tabulate results.

Compare the real specific gravity with the apparent specific gravity.

Why is the real specific gravity higher?

PRACTICE 11

Soils	Sand		Loam		Silt		Clay		Peat	
Samples	1	2	1	2	1	2	1	2	1	2
Weight of picnometer filled with water + wt. of water-free soil	....	....	....	. ..	....	....	...	....	...	....
Weight of picnometer containing soil......	...	....	....	....	....	....	....	....	....	....
Weight of water displaced	...	...	....	....	....	....	...	....	....	...
Weight of water-free soil	....	....	....	....	...	....	...	....	....	....
Specific gravity.	....	...	....	....	....	....	....	...	....	....

PRACTICE 12

Determination of Porosity.

FIRST METHOD.

Weigh the Nessler's jar or graduated cylinder.

Use sand, loam, silt, clay and peat.

Fill to the 50 or 100 cc. mark with soil not compacted and weigh. Compute the amount of water-free soil in this, using the percent of hygroscopic moisture determined in Practice 6.

$$\frac{(\text{Volume of soil x real specific gravity})-\text{Wt. of water-free soil}}{\text{Volume of soil x real specific gravity}} = \text{percent of pore space.}$$

What effect does size of particles have on total amount of pore space?

Does the amount of pore space increase or decrease with the amount of organic matter?

Which of the soils have the largest pores? Does this mean the greatest amount of pore space?

PRACTICE 12

Soil	Sand	Loam	Silt	Clay	Peat
Weight of cylinder..........	....	....	....	... .	.... . .
Wt. of cylinder + air-dry soil 1st.	... ...	....	....	....	....
Wt. of cylinder + air-dry soil 2nd	....	....	....	....	....
Av. of two trials............	... ...	....	....	..... .	....
Percent of hygroscopic moisture	....	....	....	....	....
Wt. of water-free soil.......	....	....	....	....	....
Real specific gravity.........	....	....	....	....	....
Percent of pore space......	....	....	....	....	....

PRACTICE 13

Determination of Porosity.

SECOND METHOD.

Find what percent the apparent specific gravity is of the real specific gravity and subtract this from 100 percent. The remainder expresses the percent of pore space in the soil.

Use the results in Practice 9 and 11, and determine the pore space for loose and compact soils and express the results in tabular form.

The porosity of soils varies as the apparent specific gravity.

Why?

PRACTICE 13

Soil	Sand		Loam		Silt		Clay		Peat	
Compaction	L*	C	L	C	L	C	L	C	L	C
App. specific gravity. ..	....	....	...	...	...	....	....	....	....	....
Real specific gravity......	...	....	....	....	....	..	....	....	....	....
Percent of pore space... .	....	....	....	...	.. .	...	...	....	....	...

*L=loose. C=compact.

PRACTICE 14

Determination of Loss on Ignition.

The loss that a soil suffers when it is ignited is often taken as a measure of the organic matter, but it can only be a very rough approximation at best for most soils. For some subsurface and nearly all subsoils, it gives little or no idea of the amount of organic matter. By igniting, the organic matter, volatile salts and water of hydration will be driven off. In heavy clay soils and all fine grained ones, this latter forms a very large part of the loss. Subsoils with little or no organic matter may lose as much as surface soils, due to the larger amount of clay and consequently a larger amount of water of hydration which is driven off by the heat. The more organic matter present in a soil, the nearer the loss on ignition will correspond to the real amount so that for peat soils, ignition may give a close approximation to the amount of organic matter present.

Weigh out 5 grams of water-free soil or air-dry soil calculated to a water-free basis and ignite in a small crucible to low red heat for 15 to 20 minutes. Cool in a desiccator and weigh. Determine loss for silt, loam, clay and peat.

Of which of the soils loses most? Why?

How do coarse and fine grained soils compare in loss?

PRACTICE 14

Soils	Loam		Silt		Clay		Peat	
Sample	1	2	1	2	1	2	1	2
Weight of air-dry soil								
Percent of hygroscopic moisture								
Weight of water-free soil								
Weight after ignition								
Loss in grams								
Percent of loss								

PRACTICE 15

Determination of Humus in Soils.

Weigh out five or ten grams of water-free soil, the amount taken depending upon the amount of humus in the soil. Place in filter and leach out the lime and magnesia with dilute hydrochloric acid.* When the lime is all leached out, as shown by testing the filtrate with ammonia and ammonium oxalate, wash out the hydrochloric acid with distilled water. Dry the soil and filter paper in an oven at 100° C. and put in a wide-mouthed bottle, carefully measure and add 150 cc. to 300 cc. of dilute ammonia, the amount depending upon the richness of the soil in humus. Shake for about three hours. Filter. Evaporate 50 cc. or 100 cc. of filtrate to dryness. Dry at 100° C., weigh, ignite and weigh again. The loss in weight is the humus. Calculate from the part evaporated the total amount of humus and express in percent of the water-free soil.

Of what benefit is a large amount of humus?

If an acre seven inches of soil weighs 2,000,000 pounds, how many tons of humus per acre in the soil with which you are working?

*For the dilute dydrochloric acid use 25 cc HCl sp. gr. 1.19 with 808 cc of distilled water. For the ammonia 178 cc saturated ammonia with 422 cc of distilled water

PRACTICE 15

Soils	Loam		Silt		Clay	
Sample	1	2	1	2	1	2
Weight of crucible..............	... .	......	......	......	....	......
Weight of crucible + air-dry soil......................	.....	......	......	......	.....	....
Weight of water-free soil.......	.....	.....	......	......	.....	......
Weight before ignition...	......	......	......	.....	.....	......
Weight after ignition	......	......	.....	......	.....	......
Loss of weight...	......	....	......	......	.....	......
Percent of humus........... ...	.....	......	.. ...	.....	......	. ....
Average............	.....	.....	......	......	.....	......

PRACTICE 16

Determination of Conductivity of Soils

Use sand, loam, silt, clay, and peat.

In one end of tray* place the copper vessel for the water and put asbestos plates on all sides except the one adjacent to the soil. Fill the tray with the soil to be tested. Place thermometers at a depth of 2½ inches and 1, 2, 3, 4, 5 and 6 inches from the vessel with the water and apply heat to the water through the opening in the bottom of the tray. Read thermometers about every five or ten minutes for about one hour. Tabulate results.

Students should work in sets of five, each student testing one soil and giving data to other four for comparison. Is there any relation between porosity and conductivity?

*The tray is made of galvanized iron 18 inches long by 5 inches wide and 5 inches deep. At one end of the bottom is a circular opening 2 inches in diameter through which heat is applied to the copper vessel containing water. This is 4" × 4" and five inches deep with a lid with two holes, one for a thermometer and one for the escape of steam.

PRACTICE 16

	Sand					Loam				
Time										
Temperature at 1"										
2"										
3"										
4"										
5"										
6" From source of heat										

	Silt					Clay				
Time										
Temperature at 1″										
2″										
3″										
4″										
5″										
6″ From source of heat										

	Peat									
Time										
Temperature at 1″										
2″										
3″										
4″										
5″										
6″ From source of heat										

PRACTICE 17

Power of Loose Soils to Retain Water.

Fill tubes* with sand, loam, silt, clay and peat soils. (Fill tubes about two-thirds full of peat.)

Place disks of damp cheese-cloth in the bottom of the tubes and then weigh them. Fill the tubes up to the crease (except peat) one inch from the top by pouring the soil in gently through a funnel as the tube is held vertically, being careful not to compact the soil by jarring. Weigh the filled tubes and place in an empty galvanized iron box. Pour water in the box till it is on the same level with the soil in the tubes, thus allowing the water to pass up through the soils.

Note time required for soils to become moist on top. When the soils have become thoroughly saturated, remove the tubes and place them in a pan to drain. Cover to prevent evaporation and weigh when drainage ceases.

Determine the amount of water-free soil by using the percent of hygroscopic moisture found in Practice 6.

Measure depth of the settled soils.

Calculate the percent of water retained, the weight per cubic foot of soil that this represents using the apparent specific gravity found in Practice 9, and the acre inches of water.

Land recently plowed 6 inches deep will absorb how many inches of rainfall without any run-off?

Is there any advantage in deep plowing on rolling or hilly land?

What is a saturated soil?

Why do they plow deep in semi-arid regions?

*Galvanized iron or copper tubes two inches inside diameter and twelve inches long with a crease one inch from the top. The bottom is perforated with numerous small holes and is about one-half inch from lower end of tube. There are two or three holes in main tube below this for water to enter.

PRACTICE 17

Soil	Sand	Loam	Silt	Clay	Peat
Weight of tube	......	......	.....	....	......
Weight of tube + air dry soil	......	......	.. ...	...	.....
Weight of air-dry soil	......	.....	......	......	.....
Percent of hygroscopic moisture	......	......	......	. .	......
Weight of water-free soil	......	......	.....	......	......
Time to become moist	. ...	......	......	......	.....
Depth of dry soil	......	......	......	......	......
Depth of wet soil	......	......	......	......	......
Weight of water retained	......	......	......	......	......
Percent of water retained	......	.....	......	......	......
Apparent specific gravity	......	......	......	......	......
Weight of cubic foot of soil	......	......	....	......	......
Pounds of water per cubic foot	......	......	. ....	......	......
Acre inches of water	......	......	....	......	......

PRACTICE 18

Power of Compact Soils to Retain Water

Use same tubes and soils as in Practice 17 and run at the same time if possible. Prepare the tubes in the same way but compact by letting the weight drop three times from the 12 inch mark upon each measure of soil. Fill to the crease except peat and proceed as in Practice 17.

Calculate the percent of water retained, the weight of water per cubic foot of soil using the apparent specific gravity found in Practice 9, and the acre inches of water for each soil.

Which soil becomes wet on top first? Why? How does this correspond with total pore space? Which soil is drained first? Why? How does this correspond with total pore space?

How does rolling effect the water-holding capacity of a soil?

PRACTICE 18

Soils	Sand	Loam	Silt	Clay	Peat
Weight of tube	......	......	......	......	......
Weight of tube + air-dry soil	......	......	......	......	......
Weight of air-dry soil	......	......	......	......	......
Percent of hygroscopic moisture	......	......	......	......	......
Weight of water-free soil	......	......	.	......	......
Time to become moist	......	......	...	......	......
Depth of dry soil	....	......	....	......	......
Depth of wet soil	......	......	....	......	......
Weight of water retained	......	......	......	......	......
Percent of water retained	.....	......	......	......	.....
Apparent specific gravity	......	......	......	......	......
Weight of cubic foot of soil	......	......	......	......	......
Pounds of water per cubic foot	......	......	......	......	......
Acre inches of water	.....	.....	.....	.....	......

PRACTICE 19

Effect of Organic Matter on Retention of Water

Use same tubes as in preceding practices but compact in one, sand, and in the others sand and peat in the following proportions: 95 grams of sand and 5 grams of peat thoroughly mixed, 90 grams of sand and 10 grams of peat, 80 grams of sand and 20 grams of peat and 60 grams of sand and 40 grams of peat.

Treat as in the preceding and determine the grams of water retained, also the percent of water retained based upon the total amount of sand and peat used in each tube.

How many grams of water did the 5 grams of organic matter retain? The 10 grams? The 20 grams? The 40 grams?

PRACTICE 19

Soils	Practice 18 Sand	Sand —% Peat	Sand —% Peat	Sand —% Peat	Sand —% Peat
Weight of tube					
Weight of tube + air-dry soil					
Weight of air-dry soil					
Percent of hygroscopic moisture					
Weight of water-free soil					
Time to become moist					
Depth of dry soil					
Depth of wet soil					
Weight of water retained					
Percent of water retained					
Apparent specific gravity					
Weight of cubic foot of soil					
Pounds of water per cubic foot					
Acre inches of water					
Grams of water retained by one gram of peat					

PRACTICE 20

Determination of the Rate of Percolation of Air Through Soils

This experiment requires the utmost care in order to obtain satisfactory results. Use the same aspirator* for all of the soils. Be sure that all connections are air tight. Use pressure tubing.

Fill the tubes very carefully without compacting, holding them vertically while filling. Attach the tubes successively to the aspirator after the can has been lowered in the water to the zero mark. Allow at least 4 litres of air to pass through each soil and express results in time required for 10 litres of air to pass through. Empty tubes and refill and run again as a check.

Use sand, loam and clay, compacting by letting the weight fall three times from the foot mark upon each measure of soil. Tabulate your results for both loose and compact.

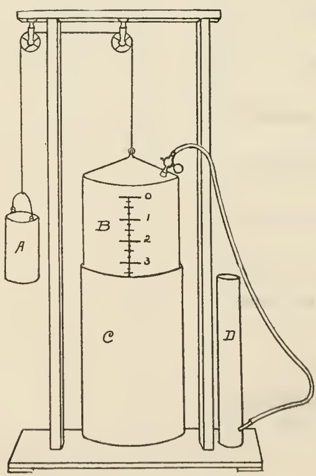
What bearing has this experiment upon aeration?

What effect does organic matter have on aeration?

What effect will moisture in the soil have upon aeration?

Try it by wetting the tube of sand and then drawing air through it.

One student may run sand with 10 grams of organic matter (peat) and another clay with the same proportion and compare with the results from the stock sand and clay. Give to the class for comparison.



*The aspirator B is made of galvanized iron, 8 inches in diameter and about 18 inches long fitted with a stopcock to which the rubber tube is attached that runs to tube D in which the soil is placed. The aspirator fits loosely in a can C filled with water. Tube D is made of galvanized iron and is 2 inches in diameter and 18 inches long with a tube for attaching to the rubber tube from the aspirator. A is the weight and should be at least twice as heavy as can B.

PRACTICE 20

	Sand		Loam		Clay	
	Loose	Compact	Loose	Compact	Loose	Compact
Time for .. litres ..	....	... .	... .	... .	... .	... ...
Time for 10 litres ..	....	....	....	....	....	... .

PRACTICE 21

Determination of the Rate of Percolation of Water Through Soils.

Fill the tubes* provided for the purpose with the soils, without compacting, to within a half inch of the overflow tube and place a layer of coarse sand one half inch deep on top to prevent the disturbance of the soil by the flowing water.

Connect the tubes as in the figure by means of short rubber tubes. Attach *a* to the water supply and *b* should lead to the waste pipe or sink for taking off the overflow. Allow the water to flow over the surface of the soil just fast enough to keep it constantly flooded. Place flasks under the tubes *c* to catch any drainage water. Note the time when water is turned on and also when percolation begins. When the flow becomes constant, the quantity of water draining from the soil in 30 minutes is determined.

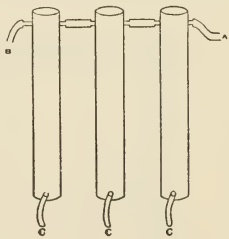
Use the same soils in the same way but compact them in the usual manner.

What application of this experiment do we see in farm practice?

From this experiment, would it be advisable to plow deep?

Would there be any advantage in fall plowing?

What objection to a sandy soil does this experiment show?



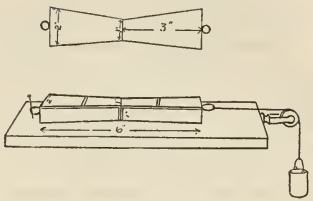
*The tubes are of galvanized iron 2 inches inside diameter. The overflow tubes, about ⅜ inch in diameter, are 1 inch from the top and the ¼ inch bent drainage tube is ½ inch from the bottom.

PRACTICE 21

	Sand		Loam		Silt	
	Loose	Compact	Loose	Compact	Loose	Compact
Time when percolation begins....	....	... ...	....	....	....	....
Amount of water percolating in 30 min......	....	....	....	.. ....	....	....

PRACTICE 22

Testing the Tenacity of Moist Soils.



Use clay, silt and loam.

Weigh out about 200 grams of each soil to be tested. Pour the soil in a pan and mix with it by hand enough water to bring it to maximum adhesiveness as near as you are able to judge.

Note amount of water used.

Now holding the cages firmly together, pack the mud into them and scrape the top off level. Attach the weight pan and carefully pour sand or fine shot into it until the soil column breaks. Weigh pan and sand. Put the movable cage in place but not having the soil surface in contact, and determine the weight necessary to overcome friction.

Subtract this from the previous weight. The result represents the tenacity of a column of moist soil one square inch in cross section.

With the same roll of mud, make three tests, using different amounts of water, noting the amount added for each soil each time.

How does fineness of grain effect tenacity?

What effect would undecomposed organic matter have on tenacity?

What term is applied to very tenacious soils?

What differences in the working of these soils?

PRACTICE 22

Soils		Silt			Loam			Clay		
Amount of water used										
Weight to overcome friction										
Breaking force	1st trial									
	2nd trial									
Average breaking force										

PRACTICE 23

Eefect of Organic Matter on Rise of Water.

Class exercise in which each member of the class is to take daily observations on the height of the water in the tubes and note effect of organic matter on rise of water.

After tying a cloth firmly over the ends of two glass two-inch tubes, 18 inches long, fill them to the height of one foot with soil compacted by letting the tube drop four times on a book for a distance of six inches for every six inches of soil put in the tube.

In one tube put about an inch of cut straw or sawdust, in the other about a half inch of well decomposed manure or peat. Fill the tubes with soil. Place the ends of the tubes in a tray and note the effect of the organic matter.

What is the effect of plowing under poorly rotted manure in the spring?

What advantage in this respect in fall plowing?

PRACTICE 24

A Study of the Capillary Power of Soils.

The capillary power of soils is influenced by several factors, the most important of these being the physical composition, texture and compactness of the soil. In field soils all of these are changed by continuous cropping and capillary action is therefore altered. Of these factors, physical composition is most important.

The soils selected are as follows:

1. Peat.
2. Sod, preferably an old blue grass pasture.
3. Heavily cropped soil as near (2) as possible so that the type of soil will be the same.
4. Clay.
5. Silt.
6. Loam.
7. Loess.
8. Sand that will pass a 100 mesh sieve but not a 120.
9. Sand that will pass an 80 mesh sieve but not a 100.
10. Sand that will pass a 60 mesh sieve but not an 80.
11. Sand that will pass a 48 mesh sieve but not a 60.
12. Sand that will pass a 20 mesh sieve but not a 40.
13. Sand and clay equal parts by weight.
14. Loess and clay equal parts by weight.
15. Loess and sand equal parts by weight.
16. Loess with 10 per cent of well ground peat.
17. Sand with 10 per cent of well ground peat.
18. Clay with 10 per cent of well ground peat.
19. Silt and 5 per cent peat.
20. Silt and 10 per cent peat.
21. Silt and 15 per cent peat.
22. Silt and 20 per cent peat.
23. Silt and 35 per cent peat.
24. Silt and 50 per cent peat.

One end of the large glass tubes is closed by means of a piece of muslin firmly tied on. These tubes are then filled with the finely pulverized and sifted air-dried soils. Great care must be exercised in filling these tubes so as not to separate the coarse and fine particles. This may best be accomplished by holding the tube vertically during the process of filling. When the tubes are filled, the soil is compacted slightly by letting each tube drop 4 times, a distance of 4 inches upon a book. The tubes are now placed in the supporting frames in such a manner that the ends shall dip one half inch beneath the surface of the water contained in the tray. The water should be turned in all trays at the same time. The experiment is now ready for observation and the data to be obtained at each reading is the total hight to which the water has risen. The readings are to be taken as nearly as possible at the intervals stated below and tabulated.

Observe hight after ½ hour, 1 hour. 2 hours, 3 hours, 6 hours, 9 hours, 12 hours, 24 hours, 36 hours, 48 hours, 3, 4, 5, 6, 7 and 8 days.

Make a close comparison of the different tubes.

Which shows the most rapid rise, 8 or 11? 6 or 7? Why?

Plot the hights of the water of the different tubes at different times?

Why does loess show a greater and more rapid rise than clay?

At the end of one hour which shows the greater rise, clay or 20 sand? Which at the end of a week? Why?

What effect does organic matter have as shown in 2 and 3, 4 and 18, 7 and 16 and 12 and 17 and 19 to 24?

What effect does size of particles have on rapidity of capillary movement not taking hight into account?

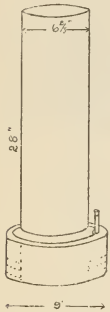
PRACTICE 24

SOILS	½ hr.	1 hr.	2 hrs.	3 hrs.	6 hrs.	9 hrs.	12 hrs.	24 hrs.	36 hrs.	48 hrs.	3 da.	4 da.	5 da.	6 da.	7 da.	8 da.
Peat																
Sod																
Heavily cropped soil																
Clay																
Silt																
Loam																
Loess																
No. 100 sand																
No. 80 sand																
No. 60 sand																
No. 40 sand																
No. 20 sand																
Sand and Clay																
Loess and Clay																
Loess and Sand																
Loess and Peat																
No. 20 sand with Peat																
Clay and Peat																
Silt and 5 % peat																
Silt and 10 % peat																
Silt and 15 % peat																
Silt and 20 % peat																
Silt and 35 % peat																
Silt and 50 % peat																

PRACTICE 25

Effect of Soil Mulches on Evaporation of Water from Soils.

Fill all of the tubes* with the same kind of soil compacting each three inches of soil added. The enlarged bases of the tube are then partially filled with water and the tubes are left till the surface soil becomes moist. The tubes are then ready for use. The water must be replaced from day to day, as it evaporates from the surface by refilling the base, the exact amount of water added in each case being noted.



The loss of water is determined by the loss in weight of the tubes. Weigh each day.

Tube 1. Check (no cultivation).
Tube 2. Cultivated 1 inch deep.
Tube 3. Cultivated 2 inches deep.
Tube 4. Cultivated 3 inches deep.
Tube 5. Cultivated 4 inches deep.

The cultivations should be made every other day to the required depth.

Each tube has an area of thirty-six square inches and the results are to be computed in tons of water evaporated per acre per week.

It is very necessary that the tubes all have the same exposure to heat and air currents.

Upon what principle does a soil mulch conserve moisture?

What effect will cultivation have on a very wet soil?

If the water table were 12 inches from the surface instead of what it is, what difference would there be in your results?

Is there any argument in the experiment in favor of fall plowing?

What argument for cultivating as soon after a beating rain as possible?

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*The tubes may be made of galvanized iron, zinc or copper. Each tube consists of two parts, a straight tube 28" long and 6¾" in diameter for holding the soil and an enlarged base 9" in diameter and 3" high for holding the water. The former is closed by tying a piece of muslin over the end. The opening of the basal part is closed by a flange about 3" from the end of the large tube. The small tube is for adding water as it evaporates.

PRACTICE 25

Soil					
Depth of Cultivation	No Cultivation	1 inch deep	2 inches deep	3 inches deep	4 inches deep
Total evaporation in grams	....	....	....	....	. .. ...
Tons per acre per week.....	.... .	....	....	....	....

PRACTICE 26

Effect of Artificial Mulches upon Evaporation of Water from Soils.

Fill tubes as in preceding exercise to within one inch of top and then fill the remaining part with material for mulch. Proceed as in Practice 25.

Tube 1. Check (filled to top with same kind of soil).

Tube 2. One inch of sand.

Tube 3. One inch of gravel.

Tube 4. One inch of peat.

Tube 5. One inch of sawdust or cut straw.

The area of each tube is thirty-six square inches.

Compute loss of water in tons per acre per week and tabulate results.

What will be the effect of these mulches on temperature?

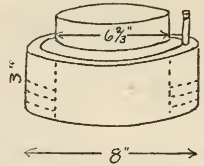
What is the principle of the growing of "Straw potatoes," i. e. covered with straw and not cultivated?

PRACTICE 26

Soil					
Mulch	No mulch	1 inch sand	1 inch gravel	1 inch peat	1 inch saw-dust
Total evaporation in grams..	....	....	....	....	....
Tons per acre per week......	....	....	....	....	....

PRACTICE 27.

Effect of Different Surfaces upon Evaporation.



Fill all tubes with the same kind of soil to within one inch of top by compacting.

Fill one tube to the top with the same kind of soil and the others with the material desired.

No. 1. Check (filled to top with same kind of soil).

No. 2. One inch of sand.

No. 3. One inch of peat.

No. 4. One inch of sawdust or cut straw.

No. 5. One inch of gravel.

No. 6. Pan of same area filled with water.

The area of each tube is thirty-six square inches.

Conduct this practice similar to preceding, computing loss of water in tons per acre per week. Tabulate results.

PRACTICE 27

Surface	Soil	Sand	Peat	Saw-dust	Gravel	Water
Total evaporation in grams.........	....	....	....	....	....	....
Tons per acre per week..........	....	....	....	....	....	....

PRACTICE 28

Use eye-piece and stage micrometers. Place both micrometers in position and determine the number of divisions or spaces of the eye-piece micrometer that correspond to 1, .1, .01 and .001 millimeters of the stage micrometer for each of the objectives.

By means of this table and the microscope with the eye-piece micrometer, it may be determined whether the separations are properly made in the following Practice.

PRACTICE 28

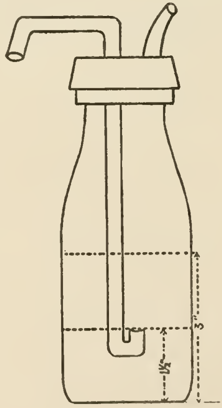
Grades	Diameter in millimeters	—— inch objective	—— inch objective	—— inch objective
Clay..........	.001–less	....	....	....
Silt....... ..	.001– .01	.. . .	....	....
Fine sand....	.01 – .1	....	....	... .
Sand.........	.1 –1.0	....	....	....
Gravel.......	1.0 –more	....	....	....

PRACTICE 29

Mechanical Analysis.

Four samples of from five to ten grams of the prepared soil are weighed out and the hygroscopic moisture determined.

Two of these are then ignited and the percent of loss on ignition is found based upon the water-free soil. Each of the other two samples is placed in a shaker bottle and about 200 cc. of distilled water and from 5 to 10 drops of ammonia are added. The bottles are then placed in the shaker and agitated till a microcopic examination of a drop of the contents shows that the soil particles are completely separated and no granules exist. When this condition is reached, the individual particles will appear clear or semi-transparent in the field of the microscope while any remaining granules will be dark, irregular and opaque. It may be necessary to continue the shaking for twelve or even twenty-four hours to completely disintegrate the soil granules. As the determination is quantitive, but a small amount of the liquid is taken from the bottle with a small glass tube and mounted on a slide for examination. When the examination is completed, the slide and cover glass are carefully rinsed with distilled water back into the bottle to recover the small portion of soil taken. Great care is necessary throughout the analysis to prevent the loss of any part of the sample, and for purposes of comparison and greater accuracy in results, duplicate samples are used.



When the microscope reveals that no compound granules remain, the samples are ready for separation into the different grades. Remove stoppers from the shaker bottles and wash them off carefully with distilled water so as to save all of the adhering particles. Make an apparatus similar to figure using an inverted 2-hole rubber stopper so large that it will close the mouth of the bottle without going in. Place in one hole a short bent tube and in the other a long tube that reaches near the bottom of the bottle. The lower end of this tube should bend suddenly upon itself so that the opening shall be upward and not downward. Adjust this tube when the apparatus is in place on the bottle so that the opening in the long tube will be 1½ inches from the bottom of the bottle. Make a mark on the bottle 3 inches from the bottom. Fill the bottles to this mark by means of a small stream of water of sufficient force to thoroughly stir up the contents.

After the liquid has stood long enough for the fine sand to settle below the end of the tube as shown by a microscopic examination of a sample compared with the sizes of the grades in the preceding exercise, the liquid is blown off into a beaker provided for the purpose. This operation of filling, settling and blowing off is repeated until the grades that settle are free from silt and clay. The liquid blown off contains silt and clay and no effort is made to separate them here.

For separating the fine sand, fill the bottles as before and allow to stand long enough for the sand (.1-1 mm.) to settle below the tube as shown by the microscope and then blow off the fine sand. Repeat until all the fine sand is blown off. The sand and gravel may be separated by the use of the millimeter sieve.

If at any time during the analysis, it is found that some of the wrong grade is blown over, it will be necessary to recover this. The water containing the silt and clay is poured into a large bottle and thoroughly shaken when an aliquot part or 500 cc. is taken and evaporated to dryness, placed in a crucible, ignited, weighed and the total amount of clay and silt determined and the percent found.

The water containing the fine sand, sand and gravel is decanted, each grade is put in a weighed crucible, dried, ignited and the percent of each grade is determined.

PRACTICE 29

Soils	Grams	Percent	Grams	Percent
Wt. of crucible				
Wt. of cru.+air dry soil				
Wt. after drying in oven				
Hygroscopic moisture				
Wt. after ignition				
Loss on ignition				
Clay, less than .001				
Silt .001–.01				
Fine sand .01–.1				
Sand .1–1				
Gravel 1–more				

PRACTICE 30

The last two weeks of the semester will be devoted to the estimation of the constituents of a larger number of soils. It is quite important that one should be able to estimate approximately the amount of gravel, sand, silt, clay and organic matter in soils and it is the object of this exercise to enable the student to do this. Each one will be given a sample of soil to be studied according to the outline below. The work is to be done rapidly and the graduated cylinder may be used as an aid in estimating the amount of each constituent.

In using the graduated cylinder, place 10 cc. of soil in it and almost fill with water. Shake thoroughly and allow it to stand for one-half minute or longer. Note the amount of sand in cubic centimeters.

Soil No.
- Dry
  - Color
  - Odor
  - Pulverulent, crumbly, cloddy.
- Moist
  - Color
  - Odor
  - Floury, mealy or gritty
  - Friable or plastic
- Composition
  - Organic matter (estimated) in percent
  - Gravel (estimated) in percent
  - Sand (estimated) in percent
  - Silt and clay (estimated) in percent
- Name of soil.

PRACTICE 31

Determination of the Effect of Cultivation and Mulches upon Temperature and Moisture.

A number of students may work at this experiment, each one being assigned a definite problem.

Select a level area of four or five square rods and remove any vegetable matter, such as weeds, etc. Break up with plow or spade all but one square rod. Place a mulch of straw or leaves several inches deep upon a half square rod of both the plowed and the unplowed. Roll a portion of the plowed area.

Determine temperature at one, two and four inches in depth on days when the sun is shining. Read the thermometer every two hours.

Determine moisture to a depth of forty inches once each week for at least four weeks.